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Drawings by C. P. Meier

CONSERVATION AND PEST CONTROL:

How Best Can Both Operate Together?

It is one of the misfortunes of the growth of knowledge that it does not advance on an even front.

Biological knowledge is, in general, acquired more slowly than chemical, and within biology there is marked unevenness of advance.

The Second World War quickened the pace of almost all scientific research and that concerned with chemical control of insect pests, fungoid diseases and of unwanted vegetation was brilliantly successful. The discovery of DDT, a chlorinated hydrocarbon, as an insecticide must have saved many lives during the war, reduced sickness rate to a remarkable degree and removed an immeasurable amount of discomfort. Immediate and urgent problems of malaria and typhus control were solved with little attention being given to possible ramifications of influence.

Shortage of labor for weeding and control of roadside vegetation gave immediate point to the use of selective herbicidal chemicals discovered during and immediately after the war. Their use has now become almost standard practice on farms, though municipal authorities use herbicides less on road verges than during the enthusiastic later 'forties. The public reacted strongly against such use of plant poisons and concurrently there were great advances in mechanical cutters and clippers for roadside work.

Nevertheless, the remarkable wartime breakthrough meant rapid development of related chlorinated hydrocarbons. Hundreds of new ones have been synthesized and some dozens have been used. It was soon discovered that DDT itself in the concentrations at first employed was toxic to fish and to many warm-blooded creatures. One of the newer compounds, benzene hexachloride or BHC, was found to be 20 times less toxic than DDT to warm-blooded animals and became the insecticide mainly used for the control of cotton insects. This differentiation and selective effect of emerging compounds gave them immediate purpose and importance. The great chemical firms spent huge sums in development of

Special Note: Through cooperative arrangement with the American Association for the Advancement of Science and other scientific groups, the Center will from time to time bring out as part of the regular series a VITAL ISSUE in the field of science on a topic especially suggested by such groups. The present VITAL ISSUE results from such an arrangement with The Conservation Foundation, a non-profit organization concerning itself with the entire subject of conservation and what people can do to help make their environment better. Since background information and objective presentation of current developments in science call for guarantees of authoritativeness, authors in this field will be specifically identified. This VITAL ISSUE was written especially for the Center by Dr. F. Fraser Darling, Vice President and Director of Research of The Conservation Foundation. Dr. Darling was formerly Senior Lecturer in Ecology, University of Edinburgh, and Director of the West Highland Survey. He has travelled widely in the United States and Africa.

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"pesticides"—the collective term now general for insecticides, fungicides, herbicides, miticides, rodenticides, and soil fumigants. The trade was worth $260,000,000 in 1956. It is expected to reach a value of $1 billion by 1975.

There are perhaps 5,000 "harmful" species of insects in the processes of cultivation and storage, though the significant ones probably do not exceed 500. Grains, fibres, fruit, and vegetables are all affected one way or another and particularly where production is geared at a high rate of commercial efficiency. Naturally, it is precisely in such conditions that the chemical insecticides show their most spectacular results.

Weeds, as plants growing in the wrong place, are a traditional nuisance, often reaching the proportions of menace. It has been said in Congress that the efforts of one worker in a chemical plant producing the most common organic herbicide 2,4-D equal the toil of 4,000 farm workers using hoes.

PROBLEMS ARISING FROM SUCCESS. The outlook for the chemical manufacturer and the commercial grower seemed bright, but seller and customer soon came against problems. The Miller Amendment of 1956, to the Food, Drug, and Cosmetic Act of 1938, established formal procedures, often costly and time-consuming, for settling tolerances of residues of chemical substances used in cultivation and production. This was also a growers' problem for it demanded a high degree of care (which had not been conspicuous earlier) in application of admittedly dangerous chemicals. And apart from residues in products, there were possibilities of dermatitis and other dangers to health among the workers applying the pesticides. Extreme care had to be learned.

It was found quite early after the Second World War that many species of insects apparently developed the power to resist the action of DDT. Selection for resistance was so rapid and so potent (occasionally up to 1,000 times the original figure) that the subject became a study in itself. Resistance is genetic, often referable to single genes, and the intensity of resistance developed is dependent on insecticidal pressure, number of years of application, proportion of the field population exposed, and the number of generations of the insect produced each year. In the public health field alone, resistance is of importance in house flies, body lice, fever mosquitoes, bed bugs, and the human flea. The World Health Organization is co-ordinating the work of 399 scientists in order to keep abreast of the phenomenon.

This resistance to insecticidal chemicals spurred the manufacturers to new syntheses of different groups of compounds, such as the now widely used organo-phosphoric insecticides, TEPP, parathion, malathion, diazinon, and dipterex. These substances not only produced a second line of attack but also proved specially suitable for certain crops, such as malathion for Mediterranean fruit fly in Florida. From the point of view of crop protection only, the chemists were quite equal in ingenuity to meet the problems which arose.

However, man does not live by bread alone, for the slightly authoritarian attitude of manufacturer and farmer, in murmuring "necessity for highest possible food production" and similar urgencies, met with a quite extraordinary wave of public opinion opposed to the unrestricted use of these pesticides. DDT was killing fish of various kinds in several states. In Pennsylvania one pound of DDT spread practically blanket fashion for gypsy moth control destroyed 70-80 per cent of the aquatic insects, many of them the food of the fish. Birds were much more resistant than fish, yet many cases of mortality arose from faulty application. Mammals were more resistant still to DDT. This chemical was found to be highly persistent in soil, so that wash-down into watercourses was continuous under a regime of frequent application. Some of the other chlorinated hydrocarbons such as aldrin, dieldrin, and endrin were much more toxic to wildlife than DDT. The organo-phosphoric compounds were also more toxic to warm-blooded animals but many of these compounds broke down readily and therefore soon became harmless.

PESTICIDES, PEOPLE, AND WILDLIFE. A battle was soon joined between lovers of wildlife and the manufacturers and users of pesticides. Steady, slow, inadequately-financed scientific investigation of the influence of pesticides on wildlife began in the late 'forties and has continued with a slowly rising budget, but a large section of public opinion was emotionally aroused and was quite ready to go far beyond the findings of the wildlife biologists in citing examples of damage and blaming the pesticides. The users of the compounds were often equally unscientific in refuting the charges. There was also a significant complaint from people who did not welcome the idea of ingesting these dangerous compounds. The Miller Amendment was on the statute book but many users of pesticides felt it could be ignored. The action of Secretary Flemming of the Department of Health, Education, and Welfare in banning the sale of some cranberries, at the very moment in November, 1959, when this fruit had a traditional festive significance, showed that the Miller Amendment had teeth. The incident must have done much to further the necessary discipline in using chemical pesticides, a discipline the manufacturers have always advised, but which users were so often slack in observing.

Another cause of anxiety is the quantities of pesticides finding their way into considerable bodies of water. The chemicals may have been used to control algae or weeds in an aquatic environment, they may have been deposited during aerial spraying, or washed into rivers and reservoirs. The United States Public Health Service at its research laboratory at Cincinnati is studying the occurrence of the compounds in water as a definite pollution problem, but it should be added that as yet no cases of human disease or mortality have been found traceable to pesticidal pollution of water. The U. S. Fish and Wildlife Service also established a Fish-Pesticide Research Laboratory at Denver in 1959.

The dangers of large-scale pesticidal application to wildlife in general have brought about a sustained public concern which the manufacturers and federal and state departments are taking seriously. The chemical firms are constantly seeking for specific toxicity in compounds and are devising means of applying them which confine their effects to the organisms at which they are aimed. For example, there are physiologically selective pesticides available against aphids and some caterpillars. Others have been made experimentally by coating small particles of insecticide with substances digestible only by plant-eating insects. If these micro-pills are eaten by predatory insects, the coating is not dissolved because the enzymes of the digestive tract are different. The manufacturers and their extremely good research teams are undoubtedly on their toes and public vigilance backed by bio-

logical research should keep them there. Pesticides are certainly here to stay and on a cost-benefit evaluation in the admittedly unnatural world in which we live, the majority of knowledgeable people will accept the fact.

SOME COSTLY AND UNFORTUNATE MISTAKES. The early stages of using new processes tend to show some unfortunate mistakes. These compounds under review were first used in a time of national urgency and thorough testing for consequences and side-effects was out of the question. This tendency to lightheartedness was a feature of the early postwar pesticide picture, but it is much less so today. Public authorities of a few years ago set in operation some ill-considered control schemes which it is highly unlikely they would repeat today. The outstanding example has been the program of the Plant Pest Control Division of the United States Department of Agriculture to eradicate the imported fire ant in the southeastern states of Georgia, Florida, Mississippi, Arkansas, Louisiana, and eastern Texas, by blanket aerial spraying of this whole vast area.

The fire ant seems to have reached Mobile from Argentina in 1918 and has since spread radially over about 27 million acres. The creature is an undoubted nuisance but not as a plant pest. Initiation of the campaign for extermination is still something of an historical mystery. How was the antipathy worked up to such a pitch that $2.4 million dollars could be voted from federal funds for the fiscal year 1957-58, to be matched from local, private, and state sources, for an operation of such immense scope and uncertain success? The propaganda build-up would have been amusing had it not been tragic in its consequences. The writer, delving in the scanty history, has come across statements that damage to a variety of crops amounted to huge sums—notwithstanding the scientific evidence that this fire ant is largely insectivorous. Brooding hens and small pigs were said to be liable to attack and the description of the onset of fatal symptoms in the stricken human being was frightening enough to precipitate an exodus, had anybody really believed it.

The aerial attack was to be from the periphery along an ever-decreasing front until a point was reached when the ant would be driven into the Gulf. Dieldrin and heptachlor, both more toxic to wildlife than DDT, were the insecticides used at the rate of 2 pounds per acre, dissolved in heavy naphtha and impregnated into dry granules of clay. The writer saw a map in March, 1960, showing the distribution of spraying to date, and was surprised to find that the peripheral plan had numerous gaps and that many penetrations in depth had been made exposing flanks. It seemed as if considerable recolonization could be expected. Farmers were exhorted after the

spraying to keep milk cows off the land for 30 days, beef cattle 15 days, and other livestock for two weeks. No advice was offered as to where the animals were to feed during these periods. J. L. George, writing in 1958, closed his account of progress to that time by saying, "hopefully, a quarter of a century and 125 million dollars from now, the present infested area (not allowing for new areas or natural die-offs) will have been treated once and the ant will have been eradicated."

Detailed studies showed that destruction of wildlife in the sprayed areas was serious and that domestic poultry also suffered. By 1960, the original dressing rate had been reduced from 2 pounds an acre to two ¼ pound applications per acre, and mortality was eased. At the moment of writing, the campaign is being soft-pedalled and it is unlikely that the original scheme will be carried through. The particular regrets on this public program are that it was put into action hurriedly without prior quantitative field testing and no arrangements were made for measuring the consequences on wildlife or habitat until treatment had begun. Even then the effort was quite inadequate. The fire ant program has roused so much valid criticism as well as mere heat that it is unlikely such a large blanket operation would be attempted in so ill-considered a fashion ever again.

THE ECOLOGICAL BACKGROUND. The opening remarks of this VITAL ISSUE deplored the slower advance of biological knowledge compared with chemical. The biological science of ecology deals with the relation of organisms to the totality of their environment and their relations between themselves. It is one of the younger sciences gaining increasing attention and recognition of importance. Obviously, the questions of how animals live (invertebrate and microscopic ones as well as those warm-blooded and large) are germane to this whole subject of pesticides. Any one type of habitat—a woodland, a prairie, or a marsh—is inhabited by a special and adapted community of plants and animals. By far the greatest number of kinds of animals are very small ones and live part or all of their lives below ground. The Danish ecologist Bornebusch estimated that the mass of animal life below the surface was equal to that above it on a well-stocked dairy farm.

This mainly unseen invertebrate life of the soil is not unimportant. Earthworms, dung beetles, root borers, and the thousand others are all fulfilling some function in the conversion cycle of matter. Simplification of this complex evolution by destruction of species slows down the conversion cycle of organic matter, which in material terms means impoverishment of the natural resources of the soil which are not to be measured only in inorganic content of calcium, nitrogen, phosphorus, and potash. A soil rich in organic matter is rich in invertebrate species of animals and micro-organisms and is in the position of being a natural buffer and sponge-like in retention of moisture. A remarkable fact is that a soil rich in organic matter and active in base exchange is able to break down pesticidal chemicals faster than an impoverished soil.

It is the opinion of the writer that the United States has long neglected the ecology of soil and fresh-water invertebrates in wildlife studies. The worms, insects, and other small creatures are not merely the *food* of fish, birds, and some mammals, but animals which have a *function* in the conversion cycle of matter. The onslaught of pesticide usage found United States biologists unable to give an answer to the question of what the chemicals were doing to the myriad organisms other than the one or the few at which the applications were aimed. But this is vital information which farmer, forester, and wildlife manager should have had *before* usage had reached the commercial scale. This knowledge is still wanting, but pesticidal application is not going to wait.

THE MULTIPRONGED APPROACH. Fortunately, there are means of tempering the harsh consequences on other living things of using the new pesticides, through thinking in terms of environment and process, of give and take, of flexibility of behavior. Take for example the aerial spraying of a spruce forest with DDT to combat budworm. Accurate observation will allow of forecasting mounting populations and spraying will be done before large areas are involved. Spraying should be done before infestations reach the higher ground. Spraying round the edge of lakes should be done when wind velocities are low, and care should always be taken of drift. Canadian scientists are now exploring the possibility of combatting build-ups of spruce budworm pop-

ulations by diversifying composition of forest stands, rendering spraying a final resort rather than the immediate remedy.

The ecological approach to lessening peak populations of pests is subtle and takes cognizance of the presence of other members of the biological community, such as in predatory relationships. After all, in very complex natural communities, such as a tropical rain forest, there are no pests, because no species in that environment builds up to pest proportions. But the mono-crop conditions of cultivation are by definition so markedly simplified that sharp rises of species to pest proportions can take place easily. Here again, however, the principle of rotation of crops is a deterrent to wild surgings of pest populations, and definite thought towards diversifying the environment helps in the same direction. This is good aesthetics as well as good husbandry. Manipulation of vegetational cover needs knowledge and insight, but it is much more interesting than immediately resorting to the chemical pesticide. In the long run it may well be better economics.

This same line of thought is apparent in what has come to be called biological control of pests—the introduction of a predator or inimical organism, or environmentally favoring the presence of natural predators. This method of attack on a pest is particularly applicable to fairly small well-defined areas, such as orchards. The initial successes on scale insects date back to the end of the 19th century. But research in biological control tends to be harder to get money for. Chemical pesticides can be tested within a year or two, but biological agents of control mean longer-term research.

Working thoughtfully on the whole problem is always harder than using a simple one-track procedure, such as the uncritical application of the chemical pesticide represents. Nevertheless, if manufacturers and users of chemical pesticides accept the premise that these substances should be always used with restraint, it will be possible in the future to arrive at knowledge which will allow the chemical, the biological, and the ecological approach to be used together. Just as in pharmacology it is known that certain drugs used together may each produce their effects when present in very small quantities, so in the control of pests there should be the primary, subtle, ecological approach, the possible employment of a biological agent (insect predator or bacterial organism), and the minimal use at the right moment of the chemical pesticide. We have seen that heavy use of such a chemical as DDT produces a rapid development of resistance. Minimal use defers the appearance of resistant populations, which from the business point of view should mean the longer life in production of any pesticidal compound.

NEEDS IN FUTURE POLICY

To sum up:

1) The increasing use of the new organic chemical pesticides demands a much greater program of field testing for effects on wildlife and soil organisms; recent legislation implies increasing federal research funds, but it is not at all clear that the scale of support will be adequate to the expansion in pesticidal application;
2) Manpower to do this work is scarce and little systematic effort is being made to produce trained men;
3) Decisions on pesticidal applications, especially on large areas, should rest on the widest possible factual base, with systematic consideration of all values concerned;
4) Ecological research on biological communities of many kinds and different grades of complexity should be looked on as being materially fruitful and not merely an academic exercise.

FOR FURTHER READING

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